# PORT PHILLIP SURVEY 1957–1963.

## BOTTOM SEDIMENTS.

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SUMMARY.

A survey of the bottom sediments of Port Phillip Bay was undertaken primarily to provide basic data for use in studying the relationships between sediment composition and the occurrence of marine animals and plants. Particle size composition is the principal sediment character studied. Three textural classifications (grade, predominant fraction and textural class) are given for each sample, and a map showing the geographic distribution of the various textural classes is presented.

The bottom sediments of Port Phillip Bay are chiefly sands, silty sands, silty clays and clays. The floor of the extensive area enclosed within the 10-fathom line in the central part of the Bay consists mainly of silty clay in its northern half and of clay in its southern half. Off the eastern shore of the Bay, out to the 6-fathom line, the bottom is mainly sand; and the floor of the Nepean Bay Bar is almost entirely sand. Westwards of the 10-fathom line to the north west shore of the Bay, sediments of finer grain size are more widespread than off the eastern shore out to the 10 fathom line. The bottom sediments of Geelong Outer Harbour and Inner Harbour (Corio Bay) are chiefly silty clay and clay.

Marine skeletal material constitutes a large portion of the sediments in some localities, high prevalence being associated usually with the coarser-grained sediments and relatively shallow water. The mineral and rock contents of the samples are discussed. In all except one sand sample, the predominant detrital mineral is quartz. Rock fragments are present in many sand and silty sand samples obtained near the shore, as well as in some samples collected several miles from the shore. The bottom sediments are considered to have been derived in part from the reworking of detritus originally deposited by rivers before the Bay was flooded by the sea about 6,000 or 7,000 years ago, and in part from detritus derived since that time from the rivers discharging into the Bay and from coastal and bottom erosion.

## INTRODUCTION.

Port Phillip Bay is an almost completely land-locked body of water, with its only opening to the sea at Port Phillip Heads which are 1 $^{9}/_{10}$ miles apart. It is about 31 miles long from north to south, and 20 miles wide at the middle, where on the west side an arm (Western Arm) extends W.S.W. for 15½ miles to Geelong. Port Phillip has a tidal area of 725 square miles, and its water depths range generally from 5 to 13 fathoms, apart from a large area of shoal water in the southern part of the Bay. The latter area constitutes the submerged land surface known as the Nepean Bay Bar (Keble, 1946), which occupies the region south of a line from Rosebud on the Nepean Peninsula to St. Leonards on the Bellarine Peninsula (see Figure 2). Through the shoals a number of channels and tideways run to The Heads. That part of Port Phillip north of the Nepean Bay Bar has been named the Inner Basin (Keble, 1946). Within it there is a large area where water depths range between 10 and 13 fathoms; and, in the central part of the Bay, an extensive area has an approximately level floor at 78 feet.

Since the physical composition of Port Phillip bottom sediments was known to vary from place to place and the geographic distribution of some bottom-dwelling animals and marine plants was thought to be closely associated with sediment type, a survey of the bottom sediments of Port Phillip was undertaken to provide more detailed information on the nature and distribution of the various sediment types. The work was carried out in association with an ecological survey of the Bay conducted as a joint project by the Victorian Fisheries and Wildlife Department and the National Museum of Victoria.

A specific objective of the survey was to ascertain the particle size composition of the sediments and to prepare a map showing the geographic distribution of the various textural classes that could be used by workers conducting the biological investigations.

## PREVIOUS KNOWLEDGE.

Although no systematic examination of Port Phillip bottom sediments has previously been carried out, some information concerning the nature of the Bay floor has been available, and erosion and sedimentation along the Bay shores has been studied.

Port Phillip was surveyed by Commander H. L. Cox in 1861, and his chart published in 1864 gives information concerning the nature of the floor of that time. The chart with corrections and additions now forms Admiralty Chart 1171 " Port Phillip ". Since 1861, various portions of the floor of Port Phillip have been dumping grounds for material (mostly silty) from dredges and barges.

Admiralty Chart 1171 contains information concerning the present Bay floor, the legend for the various bottom symbols and abbreviations being given on Chart 5011. The bottom sediment symbols on the area enclosed within the 10-fathom line, in the central part of the Bay, all indicate mud or mud and shell except for three symbols indicating shelly sand; these lie close to the southern and western margins of the area enclosed within the 10-fathom line. Offshore from the eastern coastline of the Bay the symbols indicate sand extending seaward usually to depths of 7 or 8 fathoms. Where the floor of the Bay shelves down gently from the eastern and southern shores, sand is marked as extending seaward for distances up to $3\frac{1}{2}$ miles; however, where the bathymetrical contours are closely spaced near the shore (e.g., off Mount Martha, Mornington, Mount Eliza, Rickett's Point and other steeply cliffed sections), mud is marked as close as $\frac{1}{2}$ mile to the coast. The symbols indicating fine sand off the eastern and southern shores occur at places ranging from depths of $4\frac{3}{4}$ fathoms to 8 fathoms; and a coarse sand is marked at $3\frac{1}{2}$ fathoms off Green Point, Brighton Beach. Offshore from the western coastline of the Bay mud is indicated usually in depths of more than 6 fathoms, but it is also marked in much shallower water, such as at $1\frac{3}{4}$ fathoms north of Point Cook. Almost all the soundings in Geelong Outer Harbour and Corio Bay bottom on mud, and at two places clay is marked.

Admiralty Chart 1171 has symbols indicating " stones " and " rock " at various places adjacent to and at some little distance from the shore. Usually these are offshore from high, rocky cliffs such as occur at Picnic

Point (Sandringham), Oliver's Hill (Frankston), Davy Point, Fisherman's Bay (Mornington), Balcombe Bay, Observatory Point, Point Nepean, Point Lonsdale, Indented Head and Point George; but, along the north-western shore, they are found off places such as Point Wilson, Kirk Point, Beacon Point and Point Cook where there are only low cliffs. The places marked as "reefs" on the Chart are apparently all submarine rock outcrops, as are those where the markings indicate "rock". However, the markings indicating "stones" may refer to detached rocks and minerals that have been transported.

Some data concerning the floor of Port Phillip is contained in Volume II. of the "Australia Pilot" (1956). This publication describes the natural boundary of shallow banks and a submarine rock ledge between Point Lillias and Point Henry, which separate Geelong Outer Harbour from Corio Bay. Various reefs and rocky patches, such as those off Picnic Point (Sandringham), are described in detail. Off the north-western shore of Port Phillip, from a projection about 4 miles north-east of the Werribee River mouth, a shallow, rocky spit is recorded as extending seawards about $\frac{1}{2}$ mile; and from Point Cook another shallow, rocky spit is said to extend for approximately 1 mile eastward. A reef is recorded as extending seawards to about $\frac{1}{5}$ mile east-south-east of Altona jetty; and, on a shallow bank which fronts the shore between Altona jetty and the mouth of Kororoit Creek, two rocky patches are described, the outer one lying $\frac{3}{4}$ mile offshore. According to the "Australia Pilot", the shore between the mouth of Kororoit Creek and Point Gellibrand is bordered by rocky ground which extends as far as $^{1}/_{10}$ mile offshore; and Point Gellibrand itself is bordered by rocky ground which extends about $^{3}/_{10}$ mile southward and $\frac{1}{2}$ mile east-south-eastward. Some additional information concerning the location of submarine reefs, shoals, &c., on the floor of Port Phillip is contained in "Sailing Directions, Victoria, including Bass Strait" (1959).

Following an investigation of the shores of Port Phillip Bay to ascertain where erosion and sedimentation were taking place, and in the recent past had taken place, Jutson (1931, p. 132) stated that "broadly speaking, and with certain exceptions, erosion appears to be taking place on the eastern side of the Bay, and sedimentation on the western side." He believed that the primary causes of erosion on the eastern side are the power of the waves formed by strong southerly and south-westerly winds, and the weak character of the rocks in many places—e.g., the sediments forming the cliffs between Brighton and Mordialloc are mainly poorly consolidated Tertiary and unconsolidated Quaternary sands which are easily removed. On the western shore of Port Phillip from the Yarra mouth to the north-western corner of Corio Bay, sedimentation is indicated by the occurrence of extensive Holocene marine deposits which Jutson (1931, p. 151) believed, in some instances at least, have undoubtedly been formed at present sea-level. Jutson considered that the sedimentation on the western side of the Bay might be due to the slowing down of a current bringing detritus from the Bay's eastern side, as well as to the large quantity of sediment brought into the Bay by the Yarra and Maribyrnong Rivers, and also that brought in by the Werribee and Little Rivers, and some smaller streams. Jutson's observations made around Corio Bay and Geelong Outer Harbour indicated that both sedimentation and erosion are taking place there.

Little investigation has been carried out on water currents in Port Phillip, but tidal currents are known to be strong in the southern part of the Bay. According to the "Australia Pilot" (1956, p. 76), the tidal streams in the Entrance to Port Phillip have velocities of from 5 to 8 knots at about the time of high and low water. The rate of the tidal stream is affected by the wind; a southerly wind is the prevalent wind at Port Phillip Heads, but northerlies are scarcely less prevalent. The "Australia Pilot" (1956, p. 76) records that "through the South Channel the in-going tidal stream sets at a rate of from 1 knot to $1\frac{1}{4}$ knots, whereas the out-going stream sets through at a rate of from $\frac{3}{4}$ knot to 2 knots". Keble (1946, p. 88) has stated that "the velocity of the tidal streams is practically the same from top to bottom". The tidal streams in Geelong Outer Harbour and Corio Bay are at all times feeble and irregular except where Hopetoun Channel crosses the bank between Point Henry and Point Lillias; the out-going stream there has a rate of up to 1 knot. The "Australia Pilot" (1956, p. 104) records that in Hobson's Bay the tidal streams are weak and their direction is mostly dominated by the prevailing winds. The waters of the River Yarra are almost continually running outward. Even during the in-going tidal stream the water, from the surface to a depth of about 12 feet, is running out. Under the influence of strong southerly to westerly winds, however, an upstream current is caused. The normal rate of outflow is from $\frac{1}{4}$ to $\frac{1}{2}$ knot, but this is accelerated during heavy rains when its rate may attain 4 knots.

Random observations made by boating men and skin-divers have revealed marked movements of bottom sediments in some of the shallower but fairly exposed sandy parts of the Bay; sand banks are reported to be in different positions at different times. Variations are said to be greatest after periods of rough seas with gale-force winds. Skin-divers have reported the presence of much clay and silty material suspended in the water, particularly in the north-western and northern parts of the Bay, after heavy rain and flooding of watersheds; they have observed that commonly the turbidity of the sea-water gradually extends in a south-easterly direction towards the Mornington area within several days.

Considerable movement of sand in the Nepean Bay Bar area of Port Phillip is evidenced by the fact that dredging is required to maintain the shipping channels at fixed depths.

As indicated above, submarine rock outcrops occur at various places in Port Phillip. Usually these are fairly near the shore, but some in the north-western part of the Bay occur at quite considerable distances from the shoreline. Submarine outcrops of dune-limestone occur near The Heads and extend across the Entrance to Port Phillip.

## GEOLOGICAL AND PHYSIOGRAPHIC SETTING

Port Phillip Bay is part of a larger area called the Port Phillip Sunkland, formed by the down-faulting in Cainozoic times of the region between the Rowsley Fault in the west and Selwyn's Fault in the east. Selwyn's Fault, which runs approximately parallel to the western side of the Mornington Peninsula between Frankston and Dromana, has been active since early Tertiary times, according to Hills (1960, p. 160). It is a hinge fault, the displacement dying out to the north but increasing towards the south. Gill (1964a, p. 345) has stated that the Rowsley

Fault, which runs from the Anakies north of Geelong, past Bacchus Marsh, and north towards Mount Macedon, is later than Lower Pliocene and probably Upper Pliocene in age. Subsequent flooding of part of this depressed, mainly low-lying area by the sea, due to the eustatic rise of sea-level beginning in late Pleistocene and extending to mid-Holocene times, has given rise to Port Phillip Bay. It is believed that most of Port Phillip Bay was a land surface as recently as 7,000 years ago. The topography of the land before it was submerged has largely controlled the configuration and depth of the Bay. According to Hills (1960, p. 163), Corio Bay is probably due to the drowning of a fault angle depression, bounded on the south by a fault along the northern edge of the Bellarine Peninsula.

Keble (1946), in a paper concerning the Port Phillip and Bass Strait Sunklands, stated that in Pleistocene times the land surface was drained by a river system of which the Yarra River was part. The early Yarra flowed southwards over what is now the floor of Port Phillip Bay and joined a trunk-stream, the Tamar Major River, which entered the Southern Ocean between Cape Otway and King Island. Keble (1946, p. 73) has reconstructed the valley of the Yarra during late Pleistocene and early Holocene times by connecting up soundings on Admiralty Chart 1171 into bathymetrical contour-lines. After this was done, the sunken river system showed up distinctly, and the Werribee River, Little River, Kororoit Creek, and other streams now discharging into Port Phillip are seen to have been former tributaries of the early Yarra. The eustatic rise of sea-level drowned the lower part of the river system. During eustatic low sea-levels in the Pleistocene Period, the early Yarra apparently carved out a broad valley and, in its lower reaches, flowed on a mature land surface. In Upper Pleistocene times, dune building established a bar across the " mouth " of Port Phillip; the formation and geomorphology of this Nepean Bay Bar have been described by Keble (1946, pp. 82-90). Keble interpreted the extensive area with an approximately level floor at 78 feet, north of the Nepean Bay Bar, as the delta of the Yarra River in late Pleistocene and early Holocene times. The crowding of the bathymetrical contours on the eastern side of the Bay is thought to be due to the faulting (Selwyn's Fault) plus the scouring developed thereby.

In Upper Holocene times the sea-level in Port Phillip fell some 10 or 12 feet, presumably from glacio-eustatic causes. Evidence of this emergence (raised beaches, submarine banks and shore platforms) is preserved at Hampton, Altona and other places around Port Phillip, and has been described by Hart (1893), Jutson (1931), Hills (1940), Gill (1950a; 1961; 1964b) and others.

The shoreline of Port Phillip is mostly low-lying, the main exceptions being parts of the Mornington and Bellarine Peninsulas. Keble (1946, p. 72) stated that " long stretches of the eastern shores are low and shelving—they consist mainly of littoral, alluvial or delta deposits, which have, at places, been piled up as dunes, or scoured out as submarine ridges uncovered, it is thought, by the eustatic fall of sea-level ". The eastern shore is cliffed between the various low stretches of coast. Between the north end of Port Phillip and Mordialloc the coastline is known to have receded through foreshore erosion, as it has also from Frankston to Dromana and along the north-eastern part of the Bellarine Peninsula.

The western shore of the Port Phillip Inner Basin is mainly flat and prograded, and, according to Keble (1946, p. 74), is due to the gentle tilting on a warp inshore of the almost level surface of the Werribee Plains and Keilor Plains lava-fields. The gradually sloping, south-easterly dipping basalt plain shelves beneath the waters of Port Phillip along its north-western shore.

The Bay shore of the Nepean Peninsula consists of beaches, broken by cliffs of dune-limestone. This contrasts with the shore of the Bellarine Peninsula which at Point Lonsdale and Queenscliff is cliffy, but further north is low-lying. At The Bluff (South Red Bluff), St. Leonards and other places still further north, there are low cliffs of Tertiary sandstones.

Some indications of the rocks underlying Port Phillip were obtained by a gravity survey of the Bay carried out by the Commonwealth Government. In the report of this work, Gunson, Williams and Dooley (1959, p. 2) stated that "high gravity features in the western part of Port Phillip between Altona and Portarlington may be associated with masses of basalt". The geophysical work suggests that basalt extends beneath the waters of Port Phillip in places up to 6 miles south-eastward from the present north-western shore.

Seven bores (Parl. Pap. 1864-5) put down on various sand-banks of the Nepean Bay Bar all encountered dune-limestone beneath sand ranging from 8½ to 23½ feet in thickness; and Keble (1946) considered that Pleistocene dune-limestone underlies the entire submerged land surface of the Nepean Bay Bar.

The only islands in Port Phillip are situated within the area of the Nepean Bay Bar, and they are low and sandy. The group known as Mud Islands contain small outcrops of Pleistocene dune-limestone, but Swan Island and nearby Duck Island, north of Queenscliff, have no rock outcrops. The latter islands are composed of sand ridges and silty material. In the sand ridges of Swan Island, Jutson (1931, p. 142) recorded that water-worn pebbles of ironstone, quartz, basalt and sandstone occur up to 3 or 4 inches in diameter.

The main streams discharging into Port Phillip are the Yarra River (the largest tributary of which is the Maribyrnong River), the Werribee River and the Little River. The Yarra River flows mainly over Silurian sedimentary rocks, many of which have an appreciable content of clay and silt-size particles. The Maribyrnong joins the Yarra River close to its mouth, and for many miles its valley is cut through Newer Volcanic basalt into the underlying rocks (Cainozoic sediments and Silurian rocks). Particularly following prolonged rainfall in the Yarra watershed, large quantities of silt and clay are transported in suspension by this river and discharged into the Bay.

The Werribee and Little Rivers are less important streams with shallow mouths. However, during periods of flooding their size increases considerably and they transport an appreciable amount of detrital material which is deposited in the Bay. Three much smaller creeks flow into Corio Bay.

On the eastern side of Port Phillip a few small creeks drain the swamplands of Carrum Downs and the Mornington Peninsula, but their effect in discharging detrital material is very small.

With reference to the geology of the land areas fringing the Bay, only a brief account is necessary here. The majority of the area surrounding the Bay is covered by Quaternary and Tertiary sediments and by Cainozoic basalts. Granitic rocks outcrop along the shore at Frankston, as well as at about 1 mile N.E. of the mouth of Tanti Creek (Mornington), at Mount Martha and Dromana, and they occur at Mount Eliza, Arthur's Seat, in the You Yangs and north-east from Dandenong.

The rocks of the shore platforms and cliffs along the north-eastern coastline between Brighton and Mordialloc belong to a Tertiary fluviatile-marine formation called the Sandringham Sands (Gill, 1950b); they are overlain by Holocene, wind-blown sands. The Tertiary sediments consist of ferruginous sands, sandstones and gravelstones of varying degrees of cementation and consolidation. The sands and sandstones are commonly very soft, and have quite a high clay content. Carroll (1949) found that the clay content of the Tertiary sandstones at Beaumaris averaged 19 per cent. The lowest Tertiary horizon exposed is commonly constituted of resistant ironstone. The overlying Holocene sands are generally fine-grained and have a much lower clay content than the Tertiary sediments. Most probably they were derived from pre-existing beaches from which the sand was born inland by prevailing onshore winds during the mid-Holocene arid period (Whincup, 1944). Recent dune sands occur along the coast from Mordialloc to Frankston.

Between Frankston and Mount Martha, Tertiary ferruginous sandstones (the Baxter Sandstones) occur, as well as some Tertiary shelly marls, clays and somewhat decomposed Older Volcanic basalt. Most of these rocks are easily removed by marine erosion.

On the Nepean Peninsula, Pleistocene dune-limestone outcrops extensively (Keble, 1950), and this rock also covers an area west of The Heads at Point Lonsdale and Queenscliff. Along the shores, the dune-limestone, on account of numerous contained patches of loose sand and unindurated material, is being rapidly eroded, resulting in wave-cut platforms and steep cliffs.

On the western side of the Bay, from the Yarra mouth to the north-western corner of Corio Bay, the rocks are chiefly Newer Volcanic basalt which is hard and resists erosion. The basalt occurs along the shore in the Williamstown area, at Beacon Point, Kirk Point, near Point Wilson and at Point Lillias. Elsewhere in this section of the coast, Quaternary marine deposits, composed mainly of quartzose and shelly sand with pebbles of quartz, sandstone and basalt, and alluvium occur along the shore.

At the western end of Corio Bay, cliffs of calcareous sand, sandy clay, and other sediments of Tertiary age occur along the coast. Point Henry is composed of soft clays of Upper Pliocene or Lower Pleistocene age. Along the north shore of the Bellarine Peninsula there are outcrops of Tertiary limestone, ferruginous sandstone and Older Volcanic basalt. Tertiary sedimentary rocks (mainly ferruginous sandstone) also occur on the eastern shore of the Bellarine Peninsula as far south as The Bluff.

## MATERIALS AND METHODS.

Most of the samples studied were secured by skin-divers descending to the Bay floor and pressing the top two inches of bottom sediments into a glass jar. Other samples were obtained by drag-dredging from the Fisheries and Wildlife Department's vessel "Caprella", in places where it was considered that satisfactory samples might be secured, viz., in relatively deep water where the bottom sediments were known to be stiff and sticky with a high clay content. By the dredge skimming the surface of the deposit, the top inch or so of bottom sediments along a line was collected in the dredge bag. Specimens from submarine rock outcrops and detached boulders, as well as pebbles, were collected by skin-divers wherever possible. Visual information concerning the nature of the Bay floor (e.g., ripple-marking on its surface), estimated current strength and actual movement of sediments, has been obtained from skin-diving (see Table 2).

The fixing of stations was facilitated by the division of Admiralty Chart 1171 into areas by means of a grid of 4′ of latitude by 4′ longitude using 38 S and 145 E as base references. Commencing at the north-west corner of the chart the squares of the grid were numbered in running sequence from 1 to 70. The precise location of stations from where samples were collected was determined through intersections from compass bearings on prominent landmarks, beacons, etc., the resulting position being marked on the chart.

The location of these stations is shown on Chart 2 (back of the volume), and a list of station numbers together with relevant information is given in Table A (back of volume). Samples of bottom sediments were not collected for this study from every station. An "Inshore Ferrograph" calibrated in feet was used to determine the water depth at most stations. Where it was not used, the water depth shown in the Table is that obtained from the Admiralty Charts or the depth-meters attached to skin-divers.

Fewer sediment samples were collected from areas within the 10-fathom line in the central part of the Bay, as this is largely uniform in its physical composition. Most samples were collected in depths of less than 10 fathoms where the sediments and marine life are more varied in their nature.

In brief, the laboratory procedure was as follows: The sample was dried and, where necessary, thoroughly mixed and reduced in bulk by coning and quartering to about 100 grams. Where noticeable, weed material was removed by hand picking with tweezers, and its relative abundance noted. Complete shells containing soft parts were also removed by hand. The sample was then weighed and any clay present was removed by subsidation techniques. Where necessary, a solution of sodium hexametaphosphate was added to assist the dispersion of the clay. After complete removal of the clay, the residue was dried, weighed and the percentage of clay (plus soluble salts and sometimes a little weed material) in the bottom sample was calculated. With the clay fraction removed, the material was then shaken in a nest of sieves with a mechanical shaker for 20 minutes. British Standard Series sieves were used to divide the material into the Wentworth classes listed in Table 1, except clay.

Table 1.—Wentworth Classes and Textural Grades with Corresponding Size Ranges of Each in Millimetres.

| Wentworth Classes. | Grade. | Size. (mm.) |
|---|---|---|
| Granule | Gravel | Above 2 |
| Very coarse sand | Sand | 2 to 1 |
| Coarse sand | | 1 to $\frac{1}{2}$ |
| Medium sand | | $\frac{1}{2}$ to $\frac{1}{4}$ |
| Fine sand | | $\frac{1}{4}$ to $\frac{1}{8}$ |
| Very find sand | | $\frac{1}{8}$ to $^{1}/_{16}$ |
| Silt | Silt | $^{1}/_{16}$ to $^{1}/_{256}$ |
| Clay | Clay | Below $^{1}/_{256}$ |

Following weighing, the percentages of silt, sand and gravel (where present) in the bottom sample were calculated. This quantitative data, together with the clay percentage, is recorded in Table 2. The various size fractions were examined with a hand lens or under the microscope, and significant findings concerning mineral composition, degree of grain roundness, &c., were recorded (see Table 2). The relative abundance of marine skeletal material (shell fragments, &c.) was estimated by eye in the whole sample and in certain of the size fractions, and recorded in Table 2 as A = Very abundant; a = Abundant; C = Very common; c = common; s = Scarce; S = Very scarce. Rock pebbles and specimens from submarine outcrops and detached boulders were broken (to examine fresh surfaces) and identified, when necessary, by chemical, physical and optical means.

In regard to the geographic distribution of sediment types, in presenting the data in Figure 1 it was frequently necessary to extrapolate a considerable distance. Previously published information, such as that marked by symbols and abbreviations on the Admiralty Charts, has been used as a guide in extrapolating sediment distribution.

## RESULTS.

### General.

The results of this study contain a considerable amount of new information obtained by refinements in the methods of studying the floor sediments of Port Phillip Bay. The bottom sediments of Port Phillip Bay are chiefly sands, silty sands, silty clays and clays. The floor of the extensive area enclosed within the 10-fathom line in the central part of the Bay consists mainly of silty clay in its northern half and of clay in its southern half. Off the eastern shore of the Bay, out to at least the 6-fathom line, the bottom is generally sand; and the floor of the Nepean Bay Bar, the region south of a line from Rosebud to St. Leonards, is almost entirely sand. Westwards of the 10-fathom line to the north-west shore of the Bay, sediments of finer grain size are more widespread than off the eastern shore out to the 10-fathom line. The bottom sediments of Geelong Outer Harbour and Inner Harbour (Corio Bay) are chiefly silty clay and clay; in the Outer Harbour, sand and silty sand commonly occur from the shore out to depths of 3 or 4 fathoms.

Table 2 contains the main body of data resulting from this study.

TABLE 2.—PRINCIPAL DESCRIPTIVE FEATURES OF EACH SEDIMENT SAMPLE EXAMINED, WEIGHT PERCENTAGES OF GRADES, AND ADDITIONAL INFORMATION.

| Station number. | Grade. | Predominant fraction. | Textural class. | Predominant detrital mineral matter. | Marine skeletal material. | Gravel content. (%) | Sand content. (%) | Silt content. (%) | Clay content (%)* | General Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | Sand .. | Coarse sand | Sand .. | Quartz .. | a | 1·9 | 97·4 | 0·4 | 0·3 | Ferruginous sandstone fragments present. Diver reported irregular rocky floor. |
| 11 | Sand .. | Very fine sand | Sand .. | Quartz .. | s | .. | 78·4 | 9·0 | 12·6 | Basalt fragments present. |
| 12 | Sand .. | Very fine sand | Sand .. | Quartz .. | s | .. | 79·1 | 9·0 | 11·9 | |
| 14 | Sand .. | Fine sand | Sand .. | Quartz .. | s | .. | 93·8 | 2·9 | 3·3 | Basalt fragments present |
| 15 | Sand .. | Fine sand | Sand .. | Quartz .. | c | .. | 97·9 | 1·5 | 0·6 | |
| 16 | Sand .. | Fine sand | Sand .. | Quartz .. | c | 0·3 | 98·0 | 0·1 | 1·6 | Granite fragments and biotite flakes common. |
| 17 | Sand .. | Fine sand | Sand .. | Quartz .. | c | 0·4 | 98·0 | 0·1 | 1·5 | As for No. 16 |
| 18 | Sand .. | Fine sand | Sand .. | Quartz .. | c | 0·2 | 97·8 | 0·1 | 1·9 | As for No. 16. |
| 19 | Sand .. | Fine sand | Sand .. | Quartz .. | c | 0·2 | 98·1 | 0·1 | 1·6 | As for No. 16. |
| 20 | Sand .. | Fine sand | Sand .. | Quartz .. | c | 0·2 | 98·0 | 0·1 | 1·7 | As for No. 16. |
| 21 | Sand .. | Fine sand | Sand .. | Quartz .. | c | 0·2 | 98·4 | 0·1 | 1·3 | As for No. 16. |
| 22 | Sand .. | Medium sand | Sand .. | Quartz .. | c | 1·2 | 98·5 | 0·1 | 0·2 | Ironstone particles conspicuous. |
| 30 | Sand .. | Medium sand | Sand .. | Quartz .. | c | 0·5 | 98·3 | 0·1 | 1·1 | Ironstone particles and biotite flakes conspicuous. |
| 32 | Sand .. | Fine sand | Sand .. | Quartz .. | c | 0·5 | 98·1 | 0·3 | 1·1 | Well sorted sand with biotite flakes and ironstone particles conspicuous. |
| 36 | Sand .. | Fine sand | Sand .. | Quartz .. | A | .. | 98·3 | 1·2 | 0·5 | Basalt fragments present. |
| 40 | Clay .. | Clay .. | Sand-silt-clay | Clay .. | s | .. | 20·9 | 30·0 | 49·1 | Biotite flakes present. Diver reported presence of rock. |
| 41 | Sand .. | Very coarse sand | Sand .. | Clay .. | A | 1·5 | 79·5 | 4·0 | 15·0 | A shell sand. Quartz grains scarce. Weathered basalt fragments present. |

* Clay content plus soluble salts and sometimes a little weed material

TABLE 2—*continued.*

| Station number. | Grade. | Predominant fraction. | Textural class. | Predominant detrital mineral matter. | Marine skeletal material. | Gravel content. (%) | Sand content. (%) | Silt content. (%) | Clay content (%)* | General Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 42 | Sand .. | Clay .. | Clayey sand | Quartz .. | c | .. | 58·6 | 11·0 | 30·4 | |
| 43 | Sand .. | Coarse sand | Sand .. | Quartz .. | c | 0·4 | 97·0 | 1·7 | 0·9 | Ironstone particles present. |
| 44 | Sand .. | Very fine sand | Silty sand | Quartz .. | s | .. | 55·9 | 24·7 | 19·4 | |
| 45 | Sand .. | Very fine sand | Silty sand | Quartz .. | s | 0·8 | 45·9 | 35·1 | 18·2 | Fragments of calcareous quartz sandstone present. |
| 46 | Clay .. | Clay .. | Silty clay | Quartz .. | S | .. | 22·1 | 30·0 | 47·9 | Diver reported fairly strong current. Mica flakes conspicuous. |
| 48 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 5·6 | 38·6 | 55·8 | |
| 49 | Clay .. | Clay .. | Silty clay | Clay .. | s | .. | 10·8 | 28·9 | 60·3 | |
| 51 | Sand .. | Fine sand | Sand .. | Quartz .. | c | 0·2 | 86·5 | 4·6 | 8·7 | Fragments of ferruginous sandstone and ironstone present. |
| 53 | Sand .. | Coarse sand | Sand .. | Quartz .. | A | 0·5 | 93·1 | 3·0 | 3·4 | Shelly sand containing particles of weathered basalt and ironstone. |
| 55 | Sand .. | Coarse sand | Sand .. | Quartz .. | a | 0·2 | 88·1 | 7·4 | 4·3 | Poorly sorted sand containing particles of weathered basalt and ironstone. Diver reported submarine rock outcrop. |
| 56 | Sand .. | Coarse sand | Sand .. | Quartz .. | A | 19·2 | 75·1 | 1·5 | 4·2 | Poorly sorted, shelly sand containing basalt pebbles up to 1½" in diameter. |
| 58 | Sand .. | Coarse sand | Sand .. | Quartz .. | a | 0·4 | 82·0 | 9·4 | 8·2 | Poorly sorted, shelly sand containing fragments of weathered basalt and ferruginous sandstone. |
| 59 | Sand .. | Fine sand | Sand .. | Quartz .. | S | .. | 85·7 | 5·0 | 9·3 | |

* Clay content plus soluble salts and sometimes a little weed material.

TABLE 2—*continued*

| Station Number | Grade | Predominant Fraction | Textural Class | Predominant terrigenous material | Marine skeletal material | Gravel content (%) | Sand content (%) | Silt content (%) | Clay content (%)* | General Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 | Sand | Fine sand | Sand | Quartz | S | | 95·1 | 2·4 | 2·5 | Diver reported presence of rock. |
| 61 | Sand | Medium sand | Sand | Quartz | C | | 97·2 | 1·3 | 1·5 | |
| 62 | Sand | Medium sand | Sand | Quartz | C | | 93·7 | 1·8 | 4·5 | Poorly sorted sand. Quartz grains commonly subangular. |
| 63 | Sand .. | Very fine sand | Silty sand | Quartz | S | | 61·6 | 19·9 | 18·5 | Ironstone particles conspicuous. |
| 65 | Sand .. | Coarse sand | Sand | Quartz | A | | 85·2 | 4·4 | 10·4 | Diver reported submarine rock outcrop (?basalt) |
| 66 | Sand .. | Very fine sand | Silty sand | Quartz | S | | 57·7 | 28·8 | 13·5 | Quartz grains commonly subangular. |
| 67 | Sand .. | Very fine sand | Silty sand | Quartz | S | | 69·0 | 23·8 | 7·2 | Ironstone particles conspicuous. |
| 68 | Sand .. | Fine sand | Clayey sand | Quartz | S | | 48·9 | 11·6 | 39·5 | |
| 69 | Clay .. | Clay .. | Silty clay | Clay | S | | 7·0 | 35·3 | 57·7 | |
| 70 | Clay .. | Clay .. | Silty clay | Clay | S | | 6·1 | 30·5 | 63·4 | |
| 71 | Clay .. | Clay .. | Silty clay | Clay | S | | 2·9 | 25·1 | 72·0 | Sediment dark grey in colour. |
| 72 | Clay .. | Clay | Silty clay | Clay | S | | 3·1 | 26·0 | 70·9 | |
| 74 | Sand .. | Very fine sand | Sand .. | Quartz | S | | 75·8 | 10·3 | 13·9 | |
| 75 | Sand .. | Very fine sand | Sand | Quartz | S | .. | 84·8 | 7·1 | 8·1 | |
| 76 | Sand .. | Coarse sand | Sand .. | Quartz | C | 0·2 | 98·7 | 0·1 | 1·0 | |
| 79 | Sand .. | Fine sand | Sand | Quartz | C | | 98·2 | 1·2 | 0·6 | Diver reported very strong current |
| 82 | Sand .. | Coarse sand | Sand | Quartz | C | 1·1 | 80·4 | 2·5 | 16·0 | Poorly sorted sand. Diver reported submarine rock outcrop |
| 83 | Sand .. | Coarse sand | Sand .. | Quartz | S | .. | 96·8 | 1·4 | 1·8 | |
| 92 | Sand .. | Coarse sand | Sand .. | Quartz | S | 0·4 | 96·9 | 1·1 | 1·6 | Diver reported ripple-marked floor |

* Clay content plus soluble salts and sometimes a little weed material.

TABLE 2—*continued.*

| Station number. | Grade. | Predominant fraction. | Textural class. | Predominant detrital mineral matter. | Marine skeletal material. | Gravel content. (%) | Sand content. (%) | Silt content. (%) | Clay content (%)* | General Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 93 | Sand .. | Medium sand | Sand .. | Quartz.. | c | 0·2 | 97·3 | 1·2 | 1·3 | Diver reported submarine rock outcrop. |
| 95 | Sand .. | Medium sand | Sand .. | Quartz.. | c | 0·2 | 97·9 | 1·2 | 0·7 | Diver reported submarine rock outcrop. |
| 96 | Sand .. | Medium sand | Sand .. | Quartz.. | c | .. | 98·7 | 0·1 | 1·2 | |
| 97 | Sand .. | Fine sand | Sand .. | Quartz.. | c | 1·4 | 97·1 | 0·2 | 1·3 | |
| 99 | Sand .. | Coarse sand | Sand .. | Quartz.. | C | 1·2 | 94·3 | 1·9 | 2·6 | |
| 100 | Sand .. | Coarse sand | Sand .. | Quartz.. | c | 0·9 | 97·8 | 0·1 | 1·2 | |
| 101 | Sand .. | Fine sand | Sand .. | Quartz.. | c | .. | 98·6 | 1·9 | 1·3 | |
| 103 | Silt .. | Silt .. | Clayey silt | Clay .. | s | .. | 12·6 | 72·8 | 14·6 | |
| 107 | Sand .. | Fine sand | Sand .. | Quartz.. | s | 1·9 | 96·7 | 1·1 | 0·3 | Poorly sorted sand containing basalt fragments. |
| 108 | Clay .. | Clay .. | Sand-silt-clay | Quartz.. | S | .. | 29·7 | 33·9 | 36·4 | |
| 110 | Clay .. | Clay .. | Sand-silt-clay | Quartz.. | s | .. | 23·0 | 33·1 | 43·9 | |
| 111 | Clay .. | Clay .. | Sand-silt-clay | Clay .. | s | .. | 22·7 | 26·5 | 50·8 | |
| 112 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 16·7 | 34·2 | 49·1 | |
| 114 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 18·8 | 28·4 | 52·8 | |
| 115 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 12·3 | 40·7 | 47·0 | Mica flakes conspicuous. |
| 119 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 11·8 | 35·5 | 52·7 | Mica flakes conspicuous. |
| 122 | Sand .. | Coarse sand | Sand .. | Quartz.. | c | .. | 90·7 | 4·8 | 4·5 | Poorly sorted sand. |
| 123 | Sand .. | Coarse sand | Sand .. | Quartz.. | c | 2·0 | 96·3 | 1·4 | 0·3 | Poorly sorted sand containing pebbles of calcareous rock, probably of accretionary origin. |
| 124 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 9·8 | 15·4 | 74·8 | Diver reported much suspended sediment in water. |
| 125 | Sand .. | Fine sand | Clayey sand | Quartz.. | s | .. | 71·9 | 10·5 | 17·6 | Diver reported much suspended sediment in water. |

* Clay content plus soluble salts and sometimes a little weed material.

TABLE 2—*continued.*

| Station number. | Grade. | Predominant fraction. | Textural class. | Predominant detrital mineral matter. | Marine skeletal material. | Gravel content. (%) | Sand content. (%) | Silt content. (%) | Clay content (%)* | General Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 126 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 4·3 | 36·4 | 59·3 | |
| 127 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 14·9 | 14·7 | 70·4 | |
| 128 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 1·2 | 40·0 | 58·8 | Weathered basalt particles present. Mica flakes conspicuous. |
| 129 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 3·3 | 38·3 | 58·4 | Weathered basalt particles present. |
| 130 | Silt .. | Silt .. | Sand-clay-silt | Quartz .. | s | .. | 23·3 | 48·1 | 28·6 | |
| 131 | Silt .. | Silt .. | Clayey silt | Clay .. | s | .. | 18·3 | 42·2 | 39·5 | |
| 135 | Sand .. | Coarse sand | Sand .. | Quartz .. | c | 1·1 | 95·5 | 1·6 | 1·8 | Fragments of ferruginous sandstone present. |
| 136 | Silt .. | Silt .. | Sandy silt | Quartz .. | s | .. | 36·4 | 49·3 | 14·3 | |
| 137 | Sand .. | Very coarse sand | Sand .. | Quartz .. | A | 8·5 | 85·4 | 2·1 | 4·0 | Shelly sand containing weathered basalt fragments. Diver reported submarine rock outcrop. |
| 138 | Sand .. | Very coarse sand | Silty sand | Quartz .. | A | 2·1 | 68·8 | 21·4 | 7·7 | Shelly sand containing decomposed basalt and limestone fragments. |
| 139 | Sand .. | Coarse sand | Silty sand | Clay .. | A | 2·0 | 74·8 | 11·9 | 11·3 | Shelly sand ; quartz grains scarce. Diver reported submarine rock outcrop rising 2 feet above bottom. |
| 144 | Silt .. | Silt .. | Clayey silt | Quartz .. | s | .. | 15·3 | 68·6 | 16·1 | |
| 145 | Silt .. | Silt .. | Clayey silt | Quartz .. | s | .. | 6·9 | 74·6 | 18·5 | Ironstone particles conspicuous. |
| 146 | Silt .. | Silt .. | Sandy silt | Quartz .. | s | .. | 30·6 | 61·8 | 7·6 | Ironstone particles conspicuous. |
| 147 | Sand .. | Coarse sand | Sand .. | Quartz .. | s | .. | 97·3 | 1·3 | 1·4 | Ironstone particles conspicuous. |

* Clay content plus soluble salts and sometimes a little weed material.

TABLE 2—*continued.*

| Station number. | Grade. | Predominant fraction. | Textural class. | Predominant detrital mineral matter. | Marine skeletal material. | Gravel content. (%) | Sand content. (%) | Silt content. (%) | Clay content (%)* | General Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 148 | Sand .. | Coarse sand | Sand .. | Quartz.. | a | 2·8 | 91·6 | 3·0 | 2·6 | Fragments of very ferruginous sandstone and ironstone present. Diver reported very rocky bottom. |
| 150 | Sand .. | Very coarse sand | Sand .. | Quartz.. | A | 4·5 | 94·4 | 0·4 | 0·7 | Dune-limestone fragments present. Diver reported submarine outcrop of dune-limestone. |
| 151 | Sand .. | Medium sand | Sand .. | Quartz.. | A | 0·8 | 96·5 | 1·8 | 0·9 | Dune-limestone fragments present. Diver reported flat submarine outcrop of dune-limestone with sandy patches. |
| 152 | Sand .. | Medium sand | Sand .. | Quartz.. | A | .. | 96·1 | 2·8 | 1·1 | Dune-limestone fragments present. Diver reported outcrops of dune-limestone. |
| 153 | Sand .. | Fine sand | Silty sand | Quartz.. | A | .. | 72·3 | 27·0 | 1·7 | Diver reported submarine outcrop of dune-limestone. |
| 154 | Sand .. | Fine sand | Sand .. | Quartz.. | A | .. | 94·2 | 4·7 | 1·1 | Diver reported dune-limestone fragments and very fast current. |
| 155 | Sand .. | Fine sand | Sand .. | Quartz.. | a | .. | 75·1 | 15·8 | 9·1 | |
| 156 | Sand .. | Fine sand | Sand .. | Quartz.. | a | .. | 79·7 | 14·4 | 5·9 | |
| 157 | Sand .. | Fine sand | Sand .. | Quartz.. | a | .. | 84·2 | 13·7 | 2·1 | |
| 158 | Sand .. | Fine sand | Sand .. | Quartz. | a | .. | 82·3 | 14·9 | 2·8 | |
| 159 | Silt .. | Silt .. | Clayey silt | Quartz.. | S | .. | 13·3 | 68·8 | 17·9 | |
| 160 | Sand .. | Coarse sand | Sand .. | Quartz.. | c | 1·1 | 98·5 | 0·2 | 0·2 | Hornfels pebbles present. |
| 161 | Sand .. | Coarse sand | Sand .. | Quartz.. | e | 1·4 | 98·3 | 0·1 | 0·2 | Hornfels, granite and quartz pebbles present. Biotite flakes common. |
| 162 | Sand .. | Medium sand | Sand .. | Quartz.. | s | .. | 99·2 | 0·6 | 0·2 | As for No. 161. |

* Clay content plus soluble salts and sometimes a little weed material.

TABLE 2—*continued.*

| Station number. | Grade. | Predominant fraction. | Textural class. | Predominant detrital mineral matter. | Marine skeletal material. | Gravel content. (%) | Sand content. (%) | Silt content. (%) | Clay content (%)* | General Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 163 | Sand .. | Medium sand | Sand .. | Quartz .. | c | .. | 99·1 | 0·6 | 0·3 | Diver reported submarine rock outcrop. Biotite flakes common. |
| 165 | Sand .. | Fine sand | Silty sand | Quartz .. | s | .. | 63·2 | 34·9 | 1·9 | Basalt fragments present. |
| 166 | Sand .. | Fine sand | Silty sand | Quartz .. | s | .. | 74·9 | 22·2 | 2·9 | Diver reported rock below sand. |
| 167 | Sand .. | Fine sand | Silty sand | Quartz .. | s | .. | 67·3 | 29·2 | 3·5 | |
| 168 | Sand .. | Medium sand | Sand .. | Quartz .. | a | 0·2 | 84·4 | 14·2 | 1·2 | |
| 169 | Silt .. | Silt .. | Sandy silt | Quartz .. | s | .. | 28·8 | 65·5 | 5·7 | |
| 170 | Sand .. | Fine sand | Silty sand | Quartz .. | s | .. | 69·9 | 24·7 | 5·4 | |
| 171 | Silt .. | Silt .. | Sandy silt | Quartz .. | s | .. | 28·7 | 67·2 | 4·1 | Diver reported black "mud" beneath fine sand. |
| 172 | Silt .. | Silt .. | Sandy silt | Quartz .. | s | 1·1 | 19·2 | 74·2 | 5·5 | Diver reported submarine rock outcrop. |
| 174 | Silt .. | Silt .. | Sandy silt | Quartz .. | s | .. | 38·7 | 43·8 | 17·5 | |
| 177 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 4·6 | 28·6 | 66·8 | |
| 178 | Sand .. | Fine sand | Sand .. | Quartz .. | s | 0·9 | 96·0 | 1·7 | 1·4 | Poorly sorted sand containing basalt fragments. Floor ripple-marked. |
| 179 | Sand .. | Medium sand | Sand .. | Quartz .. | c | 4·6 | 91·0 | 3·3 | 1·1 | Poorly sorted sand containing pebbles of milky quartz and fine-grained sandstone. Floor ripple-marked. |
| 184 | Sand .. | Fine sand | Sand .. | Quartz .. | c | 2·1 | 93·7 | 3·2 | 1·0 | Poorly sorted sand containing pebbles of milky quartz, weathered basalt and sandstone. |
| 186 | Sand .. | Fine sand | Sand .. | Quartz .. | c | .. | 78·9 | 18·9 | 2·2 | |
| 187 | Sand .. | Medium sand | Sand .. | Quartz .. | c | .. | 93·1 | 5·0 | 1·9 | |

* Clay content plus soluble salts and sometimes a little weed material.

TABLE 2—*continued.*

| Station number. | Grade. | Predominant fraction. | Textural class. | Predominant detrital mineral matter. | Marine skeletal material. | Gravel content. (%) | Sand content. (%) | Silt content. (%) | Clay content (%)* | General Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 191 | Sand .. | Fine sand | Sand .. | Quartz.. | c | 0·8 | 88·4 | 9·4 | 1·4 | Poorly sorted sand containing fragments of basalt and ironstone. |
| 193 | Sand .. | Fine sand | Silty sand | Quartz.. | s | .. | 73·0 | 23·5 | 3·5 | |
| 195 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 10·5 | 25·7 | 64·8 | Diver reported much sediment suspended in water. |
| 197 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 1·7 | 23·4 | 74·9 | |
| 199 | Clay .. | Clay .. | Silty clay | Clay .. | s | .. | 2·8 | 36·5 | 60·7 | |
| 200 | Sand .. | Silt .. | Silty sand | Quartz.. | s | 0·2 | 47·3 | 42·7 | 9·8 | Poorly sorted sand containing small quartz pebbles. |
| 201 | Clay .. | Clay .. | Clay .. | Clay .. | c | .. | 1·9 | 12·1 | 86·0 | |
| 202 | Sand .. | Medium sand | Sand .. | Quartz.. | c | 0·8 | 95·7 | 1·6 | 1·9 | Poorly sorted sand. |
| 204 | Sand .. | Medium sand | Gravelly sand | Quartz.. | a | 18·4 | 69·5 | 8·4 | 3·7 | Poorly sorted gravelly sand containing pebbles of ferruginous sandstone up to ½" diameter. Diver reported submarine rock outcrop. |
| 207 | Sand .. | Coarse sand | Sand .. | Quartz.. | a | 2·2 | 93·1 | 3·4 | 1·3 | Poorly sorted sand containing pebbles of ferruginous sandstone and ironstone. |
| 208 | Sand .. | Medium sand | Sand .. | Quartz.. | c | .. | 90·6 | 6·8 | 2·6 | Poorly sorted sand. |
| 209 | Clay .. | Clay .. | Silty clay | Quartz.. | S | .. | 9·4 | 44·9 | 45·7 | |
| 210 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 2·3 | 47·5 | 50·2 | |
| 211 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 1·9 | 44·4 | 53·7 | |
| 212 | Silt .. | Silt .. | Sandy silt | Quartz.. | s | .. | 22·3 | 61·9 | 15·8 | |
| 214 | Sand .. | Fine sand | Sand .. | Quartz.. | A | .. | 98·1 | 1·5 | 0·4 | Dune-limestone fragments present. |
| 217 | Sand .. | Fine sand | Sand .. | Quartz.. | a | .. | 96·3 | 2·9 | 0·8 | |

* Clay content plus soluble salts and sometimes a little weed material.

TABLE 2—*continued*.

| Station number. | Grade. | Predominant fraction. | Textural class. | Predominant detrital mineral matter. | Marine skeletal material. | Gravel content. (%) | Sand content. (%) | Silt content. (%) | Clay content (%)* | General Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 223 | Sand .. | Fine sand | Sand .. | Quartz.. | a | .. | 97·2 | 1·6 | 1·2 | Dune-limestone fragments present. Diver reported submarine rock outcrop. |
| 227 | Sand .. | Medium sand | Sand .. | Quartz.. | A | 0·3 | 98·8 | 0·5 | 0·4 | Dune-limestone fragments present. Diver reported signs of scouring. |
| 232 | Sand .. | Medium sand | Sand .. | Quartz.. | a | 9·9 | 89·2 | 0·4 | 0·5 | Fragments of dune-limestone present. |
| 233 | Sand .. | Very fine sand | Sand .. | Quartz.. | a | .. | 80·1 | 14·1 | 5·8 | |
| 237 | Sand .. | Fine sand | Clayey sand | Clay .. | A | 11·2 | 70·1 | 5·3 | 13·4 | Poorly sorted sand containing much weed. |
| 238 | Sand .. | Gravel .. | Gravelly sand | Quartz.. | A | 32·5 | 56·5 | 3·8 | 7·2 | |
| 239 | Sand .. | Medium sand | Sand .. | Quartz.. | a | 1·2 | 97·3 | 1·1 | 0·4 | |
| 240 | Sand .. | Fine sand | Sand .. | Quartz.. | a | .. | 98·3 | 1·1 | 0·6 | |
| 241 | Sand .. | Fine sand | Silty sand | Quartz.. | c | .. | 74·8 | 12·7 | 12·5 | |
| 242 | Sand .. | Fine sand | Silty sand | Quartz.. | c | .. | 66·6 | 16·8 | 16·6 | |
| 243 | Sand .. | Very fine sand | Silty sand | Quartz.. | s | .. | 55·9 | 30·1 | 14·0 | |
| 244 | Sand .. | Very fine sand | Silty sand | Quartz.. | s | .. | 67·8 | 20·9 | 11·3 | |
| 245 | Sand .. | Very fine sand | Silty sand | Quartz.. | s | .. | 74·4 | 16·3 | 9·3 | |
| 247 | Sand .. | Fine sand | Sand .. | Quartz.. | s | .. | 93·7 | 4·1 | 2·2 | Poorly sorted sand. |
| 248 | Sand .. | Very coarse sand | Sand .. | Quartz.. | s | 13·6 | 83·5 | 1·0 | 0·9 | Poorly sorted sand. |
| 252 | Clay .. | Clay .. | Clay .. | Clay .. | S | .. | 0·4 | 24·3 | 75·3 | |
| 253 | Clay .. | Clay .. | Clay .. | Clay .. | S | .. | 0·5 | 17·6 | 81·9 | |
| 254 | Clay .. | Clay .. | Sand-silt-clay | Clay .. | s | .. | 29·6 | 35·0 | 35·4 | Biotite flakes conspicuous. |
| 255 | Sand .. | Very fine sand | Sand .. | Quartz.. | s | .. | 79·6 | 12·1 | 8·3 | Biotite flakes conspicuous. |

* Clay content plus soluble salts and sometimes a little weed material.

TABLE 2 *continued.*

| Station number. | Grade. | Predominant fraction. | Textural class. | Predominant detrital mineral matter. | Marine skeletal material. | Gravel content. (%) | Sand content. (%) | Silt content. (%) | Clay content (%)* | General Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 256 | Sand .. | Coarse sand | Sand .. | Quartz.. | c | 8·0 | 90·9 | 0·6 | 0·5 | Granite fragments and biotite flakes common. |
| 257 | Sand .. | Coarse sand | Sand .. | Quartz.. | s | 1·1 | 96·3 | 1·2 | 1·4 | Well sorted sand containing ironstone particles and biotite flakes. |
| 258 | Sand .. | Very fine sand | Silty sand | Quartz.. | s | .. | 53·0 | 32·4 | 14·6 | Mica flakes conspicuous. |
| 259 | Clay .. | Clay .. | Clay .. | Clay .. | S | .. | 0·3 | 16·3 | 83·4 | |
| 260 | Clay .. | Clay .. | Clay .. | Clay .. | S | .. | 1·6 | 7·9 | 90·5 | |
| 261 | Clay .. | Clay .. | Clay .. | Clay .. | S | .. | 2·4 | 13·8 | 83·8 | |
| 262 | Clay .. | Clay .. | Clay .. | Clay .. | S | .. | 0·3 | 7·0 | 92·7 | |
| 263 | Clay .. | Clay .. | Silty clay | Clay .. | s | .. | 6·9 | 42·6 | 50·5 | |
| 266 | Sand .. | Fine sand | Sand .. | Quartz.. | a | 5·9 | 91·1 | 1·1 | 1·9 | Poorly sorted sand containing dune-limestone fragments. |
| 269 | Sand .. | Fine sand | Sand .. | Quartz.. | a | 0·9 | 96·2 | 1·6 | 1·3 | |
| 271 | Sand .. | Medium sand | Sand .. | Quartz.. | C | 2·6 | 96·1 | 1·0 | 0·3 | Diver reported sand movement with prominent ripple-marking. |
| 274 | Sand .. | Very fine sand | Silty sand | Quartz.. | c | 0·8 | 65·2 | 18·9 | 15·1 | Diver reported ripple-marked floor. |
| 275 | Sand .. | Medium sand | Sand .. | Quartz.. | A | 1·1 | 97·9 | 0·4 | 0·6 | Ferruginous sandstone fragments present. Diver reported ripple-marked floor. |
| 276 | Clay .. | Clay .. | Sand-silt-clay | Quartz.. | S | .. | 25·5 | 36·9 | 37·6 | |
| 277 | Clay .. | Clay .. | Clay .. | Clay .. | S | .. | 3·6 | 20·6 | 75·8 | |
| 278 | Sand .. | Fine sand | Silty sand | Quartz.. | s | .. | 60·8 | 31·3 | 7·9 | |
| 279 | Silt .. | Silt .. | Sand-clay-silt | Quartz | s | 4·7 | 20·9 | 38·2 | 36·2 | |
| 280 | Gravel.. | Gravel .. | Sandy gravel | Quartz.. | C | 55·7 | 43·8 | 0·3 | 0·2 | Pebbles of ferruginous sandstone and ironstone common. |

* Clay content plus soluble salts and sometimes a little weed material.

TABLE 2—*continued.*

| Station number. | Grade. | Predominant fraction. | Textural class. | Predominant detrital mineral matter. | Marine skeletal material. | Gravel content (%) | Sand content. (%) | Silt content. (%) | Clay content (%)* | General Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 281 | Sand .. | Gravel .. | Gravelly sand | Quartz.. | C | 32·5 | 64·5 | 1·9 | 1·1 | Pebbles of ferruginous sandstone common. Diver reported submarine rock outcrop. |
| 282 | Clay .. | Clay .. | Silty clay | Quartz.. | s | 1·4 | 1·7 | 46·7 | 50·2 | |
| 283 | Silt .. | Silt .. | Sand-clay-silt | Quartz.. | s | .. | 26·8 | 46·0 | 27·2 | Diver reported ripple-marked floor. |
| 284 | Sand .. | Silt .. | Silty sand | Quartz.. | a | 11·4 | 59·8 | 23·9 | 4·9 | Poorly sorted sediment containing pebbles of weathered basalt. |
| 285 | Sand .. | Medium sand | Silty sand | Quartz.. | c | .. | 69·1 | 15·6 | 15·3 | Poorly sorted sediment. |
| 286 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 1·6 | 45·6 | 52·8 | |
| 287 | Clay .. | Clay .. | Sand-silt-clay | Clay .. | s | 0·9 | 24·0 | 24·3 | 50·8 | |
| 289 | Sand .. | Fine sand | Sand .. | Quartz.. | s | 0·2 | 96·7 | 1·6 | 1·5 | |
| 292 | Sand .. | Fine sand | Sand .. | Quartz.. | c | .. | 96·3 | 1·5 | 2·2 | Diver reported submarine outcrop of dune-limestone. |
| 293 | Sand .. | Coarse sand | Sand .. | Quartz.. | c | 2·9 | 95·1 | 0·1 | 1·9 | Dune-limestone fragments and quartz pebbles present. Diver reported submarine rock outcrop. |
| 295 | Sand .. | Coarse sand | Sand .. | Quartz.. | c | 2·5 | 96·2 | 0·1 | 1·2 | Fragments of dune-limestone present. |
| 296 | Clay .. | Clay .. | Clay .. | Clay .. | s | .. | 16·6 | 8·2 | 75·2 | |
| 299 | Clay .. | Clay .. | Clay .. | Clay .. | S | .. | 1·9 | 8·5 | 89·6 | |
| 300 | Sand .. | Fine sand | Clayey sand | Quartz.. | c | 0·5 | 68·8 | 8·7 | 22·0 | |
| 302 | Clay .. | Clay .. | Clay .. | Clay .. | S | .. | 3·4 | 16·8 | 79·8 | |
| 303 | Sand .. | Fine sand | Sand .. | Quartz.. | a | .. | 97·6 | 1·0 | 1·4 | Diver reported fairly strong current and ripple-marked floor. |

* Clay content plus soluble salts and sometimes a little weed material.

TABLE 2.—*continued.*

| Station number. | Grade. | Predominant fraction. | Textural class. | Predominant detrital mineral matter. | Marine skeletal material. | Gravel content. (%) | Sand content. (%) | Silt content. (%) | Clay content (%)* | General Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 306 | Sand .. | Fine sand | Clayey sand | Quartz.. | S | .. | 58·3 | 15·4 | 26·3 | |
| 309 | Clay .. | Clay .. | Silty clay | Clay .. | c | 7·2 | 17·8 | 18·2 | 59·8 | |
| 311 | Clay .. | Clay .. | Clay .. | Clay .. | S | .. | 1·4 | 10·9 | 87·7 | |
| 313 | Sand .. | Coarse sand | Sand .. | Quartz.. | c | 9·0 | 86·6 | 0·5 | 3·9 | Poorly sorted sand. Weed material fairly common. |
| 314 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 5·6 | 19·8 | 74·6 | |
| 315 | Clay .. | Clay .. | Silty clay | Clay .. | S | .. | 3·3 | 35·1 | 61·6 | |

* Clay content plus soluble salts and sometimes a little weed material.

### Sediment Types.

Sediments can be classified according to several systems, depending upon the degree of refinement desired. In this study three classifications of sediment type have been selected: (1) grades (2) predominant fractions, and (3) textural classes.

**Grades**—The least refined classification is a series of only four categories, designated as grades. The four grades are: gravel, sand, silt, and clay. Grade designation for each sample is determined by that fraction most abundant in the sample. Size range and name of each grade are included in Table 1. The grade of each sample studied is listed in column 2 of Table 2.

**Predominant Fractions**—The classification of sediment types intermediate in degree of refinement is a group of categories termed predominant fractions. The particle-size category constituting the largest portion of the sediment sample is designated as the predominant fraction. Wentworth size classes listed in Table 1 are utilized for this classification. In column 3 of Table 2 is listed the predominant fraction of each sediment sample studied.

**Textural Classes**—The most refined classification of sediment types is termed textural classes. This is essentially a modification of the first classification (Grades). The most abundant grade, based on weight, is complemented by the second ranking grade, and the result is a binary term expressing the two major constituents of each sediment. An exception to this rule is when one grade constitutes 75 per cent. or more of any one sample. In such sediments the term is limited to a single grade. Among the samples analyzed, sand and clay are the only two classes that fall in this category. In sediments where three grades each provide 20 per cent. or more of the entire sample, all three grades are identified in the textural class terms. Sand-silt-clay and sand-clay-silt are the only representatives of this type of textural class encountered in this study. This procedure is in accordance with the system devised by Shepard (1953). The textural class of each sediment sample is listed in column 4 of Table 2; the geographic distribution is illustrated in Figure 1.

The most striking features of the textural class distribution have been mentioned above. Another major feature shown in Figure 1 is the extensive tract of silty sand located north of the Bellarine Peninsula and extending in a westerly direction to the shoreline and in a north-easterly direction as far as Williamstown. A further conspicuous feature is an extensive area of sand off the north-western shores of Port Phillip; it has a maximum width of 5½ miles east of the Werribee River mouth where it extends out to depths of more than 6 fathoms, but it decreases in width considerably to the south-west, terminating bluntly about ¾ mile south of the Little River mouth. To the north-east this tract of sand extends as far as Altona, generally tapering in width; and, in the northern part, sand extends out to only about the 4-fathom line.

The central and western parts of Hobson's Bay and the area immediately to the south contain areas that have been deepened by dredging and also some regions where dredged material has been dumped.

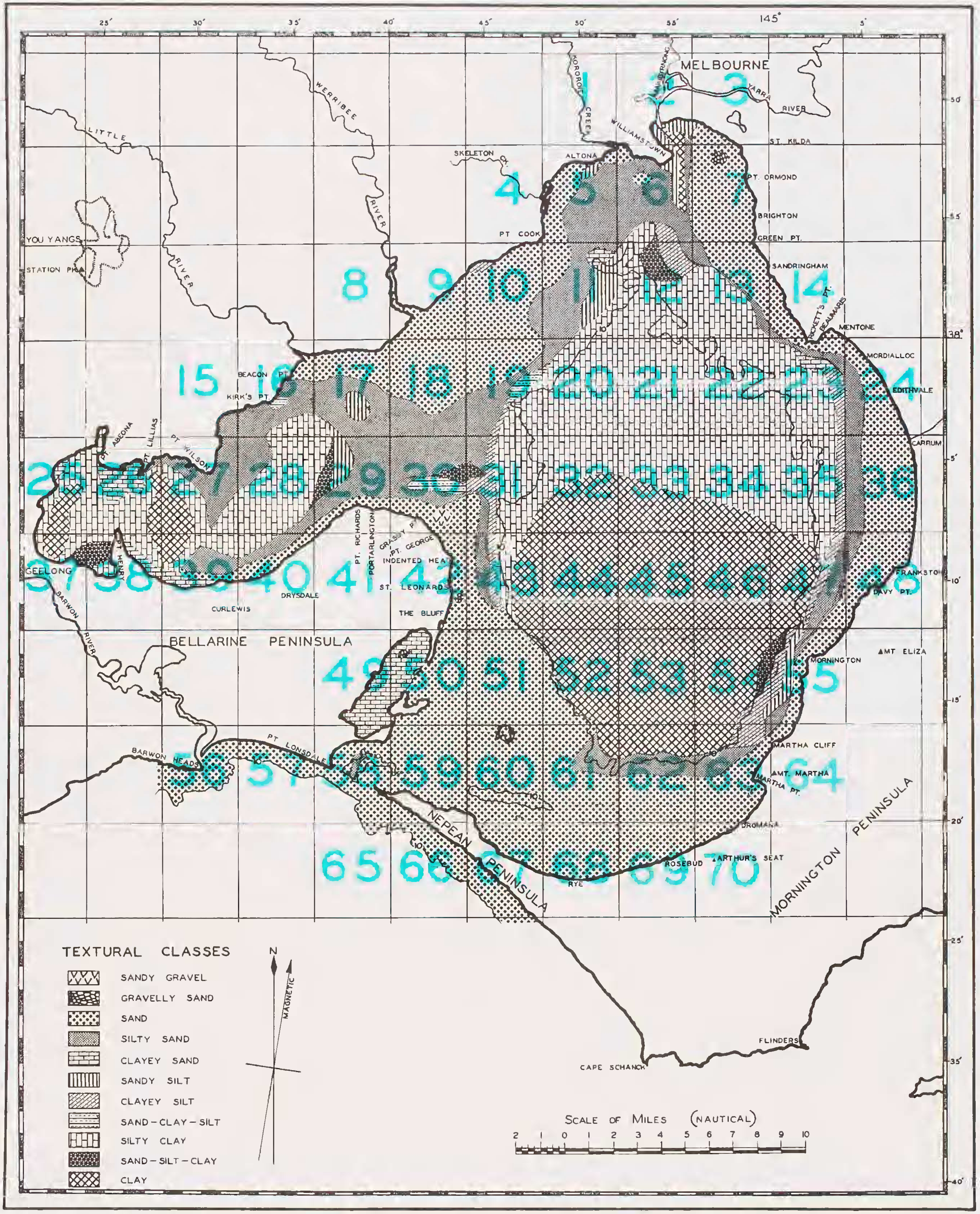


FIG. 1—Geographic distribution of sediment textural classes.

The sediments of the eastern part of Hobson's Bay and the area immediately to the south are sands, and sand extends almost as far west as the dredged Port Melbourne Channel. The floor of the shipping Channel is essentially clay, and, parallel to it, immediately to the east, there is a narrow belt of silty sand. Immediately to the west of the Port Melbourne Channel, sandy silt occurs in a narrow tract extending northwards to Williamstown. Sandy silt also extends from the western shore of Hobson's Bay to the dredged River Entrance Channel, as well as southwards offshore from between the Yarra mouth and Station Pier, Port Melbourne.

In the eastern part of Port Phillip there is a long, relatively narrow tract of silty sand roughly parallel to most of the eastern coastline; this belt occurs at an average depth of about 8 fathoms. To the east, this silty sand passes into sand and, to the west, between the latitudes of Mordialloc and Mornington, it passes into clayey silt. Elsewhere, on its western side, the silty sand passes into clayey sand, sandy silt, clayey silt and silty clay.

The belt of sand adjacent to the eastern shore of the Bay has a maximum width of $2\frac{3}{4}$ miles off Brighton. It is wide in the north-eastern part of the Bay where the bathymetric contours are far apart, but tapers in a south-easterly direction to a width of only $\frac{1}{3}$ mile off Rickett's Point where the bathymetric contours are closely spaced. South from Mentone this coastal belt of sand widens to a width of $2\frac{1}{3}$ miles off Carrum and Seaford and then gradually tapers to a width of less than $\frac{1}{2}$ mile off Mornington. Offshore between Mornington and Martha Cliff, where the bathymetric contours are very closely spaced near the shore, the coastal belt of sand averages about $\frac{1}{2}$ mile in width; but offshore between Martha Cliff and Martha Point the belt widens, enlarging considerably south of Martha Point.

To the west of the sandy belt between Mornington and Mount Martha, there are four sediment textural classes in an area approximately $5\frac{1}{2}$ miles in length by $1\frac{1}{2}$ miles in width. In this region, areas of silty sand, sandy silt and clayey silt abut on the coastal sand belt at different places. However, the silty sand is mainly in water shallower than the sandy silt, and the clayey silt in water deeper than the sandy silt. Offshore from Mornington, just west of and roughly parallel with the 10-fathom line, there is a lens-shaped area of sand-silt-clay, passing into clayey silt on its eastern side and into clay on its western side.

In the southern part of the Bay there is an east-west veering tract of silty sand approximately parallel with the 10-fathom line offshore between Dromana and Rye. This tract has an average width of $\frac{5}{8}$ mile and occurs at depths of about 8 to 10 fathoms. On its southern side the silty sand passes into sand, and on its northern side into clay.

In the deep water of Lonsdale Bight and the adjacent area near The Heads a narrow tract of silty sand occurs. Outside The Heads all of the bottom sediments examined as far as the 10-fathom line are sands, no sediments of finer grain-size being found. Admiralty Chart 1171 indicates that sand occurs to depths of more than 40 fathoms in Bass Strait.

Much of the north-east front of the Nepean Bay Bar is characterized by an abrupt change of sediment type from sand to clay, with either no intermediate textural classes or only very minor developments of certain classes. This abrupt change occurs at about the 10-fathom line, which for some long stretches is very close to the 6, 5, and 3-fathom lines. For about 2 miles the 10-fathom line is also very close to the 13-fathom line.

The large area of clay in the southern part of the Inner Basin passes into silty clay to the north and to the north-west. Almost all of the Bay floor enclosed within the 13-fathom line is covered by clay.

The bottom sediments of Swan Bay are essentially clayey sands but, in the northern part, gravelly shell sand is found. An area of gravelly sand also occurs near the shore east-south-east of St. Leonards.

Offshore from the north-eastern part of the Bellarine Peninsula a belt of silty sand extends in a north-south direction for about 4¾ miles, with sand on its western side and clayey silt on its eastern side.

The belt of sand adjacent to the north-eastern shores of the Bellarine Peninsula has a maximum width of 2½ miles off Point George. This location is in Prince George Bank, a region which contains an area of sandy gravel as well as a number of submarine rock outcrops. The tract of sand adjacent to the northern shore of the Bellarine Peninsula from Grassy Point westward to about north of Curlewis is relatively narrow, averaging about ½ mile in width. It passes into silty sand to the north, and tapers to extinction to the west.

About 1½ miles offshore from the north-eastern part of the Bellarine Peninsula there is an elongate area of sand-clay-silt. It passes into silty sand to the south and west and into a lenticular area of sand-silt-clay to the north-east. Both the sand-clay-silt and sand-silt-clay areas pass on the east into clayey silt.

Adjacent to the southern shore of Geelong Outer Harbour, from about north of Curlewis nearly to Point Henry, there is a belt of clayey sand that averages about ⅓ mile in width; for most of its length it passes into silty clay to the north.

A large area of clay occurs in Geelong Outer Harbour. It is roughly oval-shaped and elongated in a north-south direction, and approaches to within ¼ mile of the northern shoreline and about ¾ mile of the southern shoreline. This clay area is completely surrounded by silty clay, and silty clay extends for about 7 miles in a north-easterly direction. This silty clay passes mainly into silty sand to the north and south, but, in its most eastern part, it passes into a lenticular area of sand-silt-clay. This latter textural class is about 3 miles in length by ¼ mile in width, and passes into sandy silt and silty sand to the east. South of Point Wilson, a tongue-shaped area of silty sand extends from the shore for a distance of about 2¼ miles, and immediately to the south the belt of silty sand off the southern shore of Geelong Outer Harbour attains a width of 1¼ miles; a floor of silty clay about ½ mile wide, part of which is a dredged channel, separates it from the tip of the Point Wilson "tongue". Accordingly, from Point Wilson southwards, silty sand extends nearly across Geelong Outer Harbour.

In Corio Bay there is also a large area of clay. It is elongated in a north-south direction and approaches to within $\frac{1}{8}$ mile of the southern shoreline and $\frac{1}{6}$ mile of the western shoreline. This clay area occurs almost entirely in water deeper than 5 fathoms, and part of it has been deepened by dredging operations. It is entirely surrounded by silty clay which extends for about $1\frac{1}{2}$ miles to the northern shore of Corio Bay and stretches in an easterly direction past Point Henry into Geelong Outer Harbour. In the shallow, south-eastern part of Corio Bay, known as Stingaree Bay, there is an area of sand-silt-clay, and this textural class passes into silty clay to the south and north. The south-eastern part of Corio Bay, west of the Point Henry Peninsula, contains a spoil ground and a considerable amount of dredged material has been dumped there. Adjacent to the north-western shore of Corio Bay there is a narrow tract of clayey sand, and clayey sand also extends southwards from the northern shore between Point Abeona and Point Lillias for distances up to $1\frac{1}{2}$ miles. Both areas of clayey sand pass into silty clay.

Approximately 2 miles south-west of the Little River mouth, adjacent to the shore, there is a small area of sand-clay-silt which passes into silty sand; and about $3\frac{1}{2}$ miles to the east of this there occurs a larger area of sandy silt completely surrounded by silty sand.

The large area of silty clay in the northern part of the Inner Basin extends landwards generally to depths of between 8 and 9 fathoms. Proceeding from south to north along its western margin, the silty clay passes into clayey silt, clayey sand, silty sand and sandy silt. The clayey silt occurs mainly as a narrow belt, and passes at its northern end into a lens-shaped area of clayey sand, situated about 9 miles east of the Little River mouth. This clayey sand extends in a north-easterly direction for about $2\frac{3}{4}$ miles and passes to the north into a region of silty sand. The sandy silt abutting on the north-western edge of the large area of silty clay extends northwards for about $3\frac{1}{2}$ miles; it has a width of about 1 mile and merges to the north into a small area of clayey sand. Abutting on the north-north-eastern edge of the silty clay there are areas of sand-silt-clay and clayey silt. The sand-silt-clay area passes to the north-east into a somewhat larger area of clayey silt which in turn passes into silty sand. To the south-east of these areas, and proceeding southwards, the silty clay passes, on its eastern margin, into relatively narrow tracts of silty sand, clayey sand and clayey silt. The clayey sand occurs as a lens-shaped area approximately 1 mile south of Rickett's Point; it is about 2 miles in length and has a maximum width of $\frac{1}{2}$ mile.

In the northern part of the Bay silty sand covers a large area. It extends from Williamstown southward for nearly 3 miles and has a width of $4\frac{1}{2}$ miles from about 1 mile east of Skeleton Creek mouth eastwards towards the dredged Port Melbourne Channel. The silty sand south of this Channel passes to the east into sand.

### Content of Marine Skeletal Material.

Marine skeletal material (shell fragments, whole shells, echinoid spines, etc.) constitutes a large portion of the sediments in some localities. The relative abundance of marine skeletal material in each bottom sample was recorded by symbols, and is listed in column 6 of Table 2.

In general, high prevalence of marine skeletal material is associated with the coarser-grained sediments (sandy gravel, gravelly sand, sand and silty sand) and relatively shallow water. In relatively deep water and where the bottom is composed of fine-grained sediments, marine skeletal material generally is not common. The content of marine skeletal material is usually high in the vicinity of submarine rock outcrops and submarine accumulations of detached rock pebbles and boulders; commonly these rocks are fairly close to the shore.

Marine skeletal material is particularly prevalent in the bottom sediments of the Nepean Bay Bar, which is essentially an area of shoal water. This shoal water contains submarine outcrops of dune-limestone, and this rock, which itself contains much marine skeletal material, occurs as cliffs and rock platforms along the shore.

Marine skeletal material is very abundant in the sediment samples examined from Swan Bay, and is common in all samples examined from outside Port Phillip Heads (on the landward side of the 10-fathom line).

In most sediment samples obtained at depths of less than 6 fathoms off the eastern shores of the Bellarine Peninsula, marine skeletal material is quite prevalent, and it ranges from abundant to very abundant in bottom samples from Prince George Bank.

Close off the southern shore of Geelong Outer Harbour about north of Curlewis, marine skeletal material is common in the samples of sand and clayey sand, and it is also common in the clayey sand south-west of Point Lillias.

Offshore in the vicinity of Point Wilson and in the Spit region to the south, marine skeletal material is very abundant in the silty sand, and to the north-east of Point Wilson it ranges from common to abundant in the silty sand.

East and south of the Werribee River mouth, marine skeletal material is common in the sand samples, and offshore from Point Cook, also in sand, it ranges from common to very abundant. It is more prevalent in the samples from shallower water, closer to the shore, than in those from deeper water.

Offshore from Altona, marine skeletal material is abundant in the sand, and south of the mouth of Kororoit Creek, as well as to the south-east (off Williamstown), it is very abundant in the sand samples.

Marine skeletal material is common in the sand that occurs offshore from Port Melbourne, and it is abundant in the gravelly sand offshore from St. Kilda. In the sand samples examined from west of Brighton, marine skeletal material ranges from common to abundant, and it is common in the sand offshore from Sandringham.

In sand samples collected offshore between Edithvale and Seaford at depths of 5 fathoms and less, marine skeletal material is common, as also in the sand close to the shore between Canadian Bay (south of Frankston) and Mornington. At a depth of $3\frac{1}{2}$ fathoms just south of

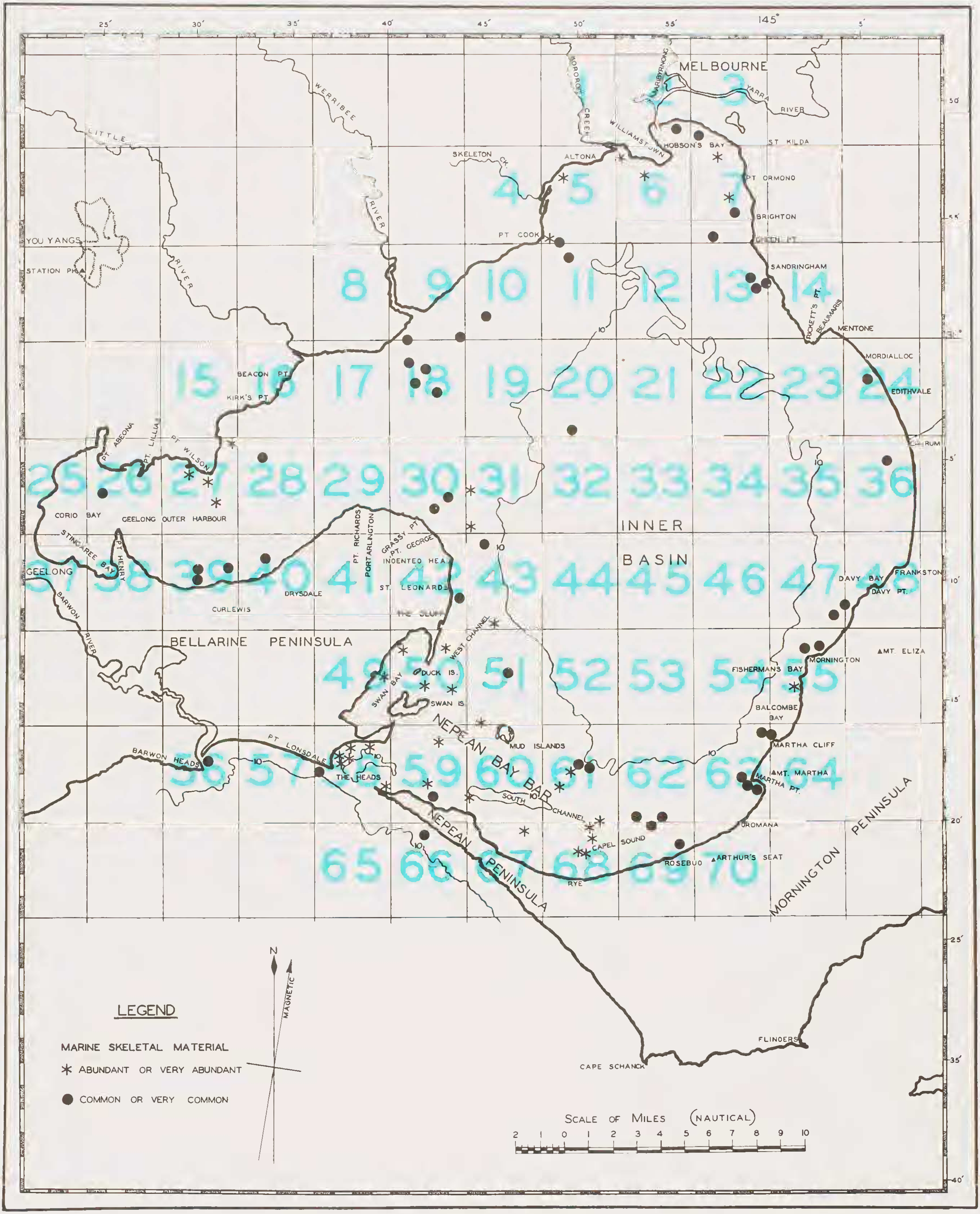


FIG. 2—Stations where prevalence of marine skeletal material is high.

Fisherman Point, Mornington, marine skeletal material is abundant in the sand, and it is common in the sand from depths of 5 fathoms and less off Martha Cliff. Shell fragments are also common in the sand samples obtained close to the shore off Martha Point and close off the granitic cliffs of Dromana Bay.

In the large area enclosed within the 10-fathom line, in the central part of the Bay, marine skeletal material is generally scarce or very scarce. It is common in only one of the samples examined; this is a sample of silty clay containing small whole shells, and was collected from about 8 miles south-east of the Werribee River mouth.

In other areas of silty clay and clay, such as occur in Geelong Outer Harbour and Corio Bay, marine skeletal material is also scarce or very scarce.

### Weed Content.

Weed material was largely removed from the dry sample by hand picking with tweezers, and its relative abundance noted. In some samples, a little weed material was also removed and noted during decantation of the clay fraction.

The weed content of the dry samples of bottom sediments commonly reflects the relative abundance of weed growing on the various sediment textural classes in different parts of the Bay. In general, weed material was not common in the sand samples obtained by the skin-divers. It was found to be very scarce in the samples of silty clay and clay from the large areas of these textural classes in the deep, central part of the Bay. Generally, weed material was not common in samples obtained from depths greater than 5 or 6 fathoms.

Weed material was most common in samples of clayey sand and silty sand obtained from sheltered regions such as Swan Bay, parts of Geelong Outer Harbour and Corio Bay. It was also fairly common in certain samples of silty sand obtained offshore from the north-western coastline of the Bay.

### Mineral and Rock Contents.

The detrital mineral matter predominating in each sediment sample is listed in column 5 of Table 2. In nearly all samples of sand, the predominant mineral is quartz. In samples from the belt of sand adjacent to the eastern shore, from Port Melbourne southward to about Balcombe Bay, the quartz grains are often ironstained and reveal films of brownish and yellowish secondary iron hydroxide along cracks and flaws; an abundance of ironstained grains has contributed to the overall yellowish colour of some of the sand samples.

In many of the sand samples obtained off the north-eastern shore of the Bay, between Port Melbourne and Mordialloc, fragments of ferruginous sandstone and ironstone are present; such samples generally are poorly sorted and some contain fragments of other rocks such as chert and calcareous standstone. Submarine rock outcrops and accumulations of pebbles and boulders were reported by skin-divers in the vicinity of some of these sample locations. Heavy minerals constitute a small percentage of all the sand samples studied from this north-eastern part of the Bay; they are mostly opaque oxides—mainly black grains of ilmenite and magnetite and brown grains of limonite.

Many of the sand samples obtained offshore between Frankston and Balcombe Bay also contain fragments of ferruginous sandstone, and flakes of biotite are often conspicuous. On the Bay floor in this region, rock outcrops and accumulations of pebbles and boulders are not uncommon.

In samples obtained from the coastal belt of sand offshore from about Martha Cliff southwards to Rosebud, the quartz grains are usually not iron-stained, and this also applies to the sand samples from the Nepean Bay Bar area.

Off the granodiorite coast from Martha Cliff southwards to Safety Beach, Dromana, biotite flakes are conspicuous in the sand samples; and quartz and felspar granules, as well as granite, hornfels and quartz pebbles are present in some samples. Most of these sands are poorly sorted, as are those examined from the Dromana Bay area to the south.

About 1 mile offshore from Rosebud, pebbles of dune-limestone are found in the sand, and fragments of this rock are present in most of the sand samples obtained off the northern shore of the Nepean Peninsula between Sorrento and Point Nepean. Submarine outcrops of dune-limestone, $\frac{1}{4}$ mile offshore, were reported by the skin-divers in this region, as well as off Point Lonsdale and in the Lonsdale Bight between Point Lonsdale and Shortland Bluff, Queenscliff.

Outside Port Phillip Heads, fragments of dune-limestone are present in all the sand samples examined, and submarine outcrops of this rock were located up to $\frac{3}{4}$ mile offshore.

Dune-limestone fragments are also present in many of the sand samples obtained off the south-eastern part of the Bellarine Peninsula from Point Lonsdale northwards almost to St. Leonards, even being found as far as two miles offshore from just south of The Bluff.

Off the Bellarine Peninsula between The Bluff and Portarlington, fragments of ferruginous sandstone are not uncommon in the sand. The gravelly sand that occurs near the shore east-south-east of St. Leonards contains numerous pebbles of ferruginous sandstone, and a sandstone outcrop was found in the vicinity of station number 281. Submarine outcrops of ferruginous sandstone and accumulations of boulders and pebbles of this rock are particularly common off Indented Head and Point George. Fragments of ferruginous sandstone were found in the sand as far as $1\frac{1}{2}$ miles to the east and $2\frac{1}{4}$ miles to the north-east of Point George, near the margin of the Prince George Bank. Dredging just south of the Prince George Light yielded quite large boulders of ferruginous sandstone. In the sandy gravel to the east of Grassy Point, granules and pebbles of ferruginous sandstone are very common and submarine outcrops of this rock were located.

Offshore from Portarlington, basalt fragments are present in the sand, and in the sand bordering the southern shore of Geelong Outer Harbour, about north of Curlewis, there are fragments of calcareous quartz sandstone. These sands generally are poorly sorted.

Fragments of weathered basalt occur in the silty sand off the northern shore of Geelong Outer Harbour in the vicinity of Point Wilson, and diving revealed submarine outcrops of basalt rising 2 feet above the floor about $\frac{1}{2}$ mile south of Point Wilson. In this silty sand, quartz grains are not very common. Fragments of decomposed basalt occur in the silty sand as far as $1\frac{1}{2}$ miles south of Point Wilson, and dredging operations about $2\frac{1}{4}$ miles to the south of Point Wilson have exposed solid basalt beneath silty clay.

To the north-north-east of Point Wilson and about $\frac{1}{2}$ mile offshore, fragments of weathered basalt occur in the silty sand. Diving has revealed a submarine outcrop of basalt at station number 172, about 3 miles south-east of the Little River mouth.

In the sandy sediments offshore between the mouth of the Little River and that of the Werribee River, granules and pebbles of vein quartz, weathered basalt, sandstone and impure limestone occur at various places, as far as 2 miles from the coastline. The sands of this region are generally poorly sorted and the quartz grains are commonly subangular. At station number 60, about $2\frac{1}{2}$ miles offshore, rock (? basalt outcrop) was reported by a skin-diver. Just north of the Werribee River mouth, basalt boulders and pebbles are found in the intertidal zone, and in the sand near the river mouth basalt fragments occur.

At station numbers 11 and 14, about 5 miles and 4 miles respectively to the east of the Werribee River mouth, small fragments of basalt are present in the sand.

Offshore from Point Cook, ferruginous sandstone, ironstone and basalt fragments occur in the sand samples collected from as far as $1\frac{1}{4}$ miles to the east-south-east of the Point. At station number 56, about $\frac{1}{4}$ mile east of Point Cook, the basalt pebbles range up to $1\frac{1}{2}$ inches in diameter. All sand samples examined from this region are poorly sorted. About $\frac{3}{8}$ mile east of Point Cook, a submarine rock outcrop believed to be basalt was reported by the skin-diver. Apparently this is part of the shallow rocky spit which, according to the "Australia Pilot", extends for approximately 1 mile eastward from Point Cook.

At station number 165, about $2\frac{1}{4}$ miles north-east of Point Cook, basalt granules occur in the silty sand; and basalt is present below silty sand at station 166, approximately $2\frac{1}{4}$ miles east-north-east of Point Cook.

About 1 mile east of Altona, fragments of weathered basalt occur in the sand, and the diver reported a submarine rock outcrop there. Another submarine rock outcrop, believed to be basalt, was reported in the vicinity of station number 65, approximately 2 miles south-east of Altona.

The silty sand at station number 200, about 2¼ miles south-south-west of Point Gellibrand, is poorly sorted and contains quartz granules and small quartz pebbles.

The sand and silty sand samples from off the north-western shore of Port Phillip Bay contain a small percentage of heavy minerals; the heavies are mostly opaque oxides—ilmenite, leucoxene, magnetite and limonite. However, grains of olivine, zircon, augite, rutile and tourmaline were recognized in some of the samples.

Clay minerals make up 75 per cent. or more of all the clay samples, and they constitute the predominant mineral matter in all except two of the samples of silty clay. Flakes of mica are conspicuous in some samples of silty clay from the northern portion of the large area enclosed within the 10-fathom line. Biotite flakes are conspicuous in the sand-silt-clay at station number 254, west of Mornington at a depth of 10 fathoms.

The shelly sands at station numbers 41 and 139, offshore in the vicinity of Point Wilson, have clay as their predominant mineral matter.

## DISCUSSION AND INTERPRETATION.

Port Phillip Bay is an almost completely land-locked body of water with a bar of dune-limestone and sandbanks extending across its opening to the sea. It is believed to have existed more or less in its present form since mid-Holocene times. In mid-Holocene times, when the climate was slightly warmer than at present (Dorman and Gill, 1958), sea-level was of the order of 10 feet higher and the Bay was somewhat larger, covering low-lying, fringing regions particularly in the north-west.

For several thousand years sediment has been continuously deposited in the Bay and has been gradually accumulating. Sediments of terrigenous origin (mainly silts and clays) have been discharged from rivers into the Bay and carried to various areas in suspension and along the floor. Sediments derived from the marine erosion of the rocks and unconsolidated detrital materials around the Bay shores have gradually been spread over the bottom by wave action and currents. It appears to the writer that almost all these sediments have been effectively trapped in the Bay for 6,000 or 7,000 years. Evidence from the radiocarbon dating of wood (Gill, 1956) indicates that about 8,750 years ago the sea was at least 73 feet lower than now, so most of Port Phillip Bay is known to have been dry land at that time. Although no quantitative information is available concerning the rate of sedimentation on the Bay floor, it is considered that many of the bottom samples studied represent detritus of middle and late Holocene age; they consist only of the top 2 inches of sediment. However, some of the samples are believed to contain material of fluviatile origin, derived from the rivers that flowed over the floor of Port Phillip Bay before it was flooded by the sea 6,000 or 7,000 years ago. Such material of early Holocene and perhaps late Pleistocene age is considered to form part of the bottom sediments more particularly in certain areas, such as those comparatively distant from the present shoreline and river mouths. With the gradual rise in sea-level which flooded Port Phillip Bay, there must have been much reworking of the detrital materials that covered the original floor. Reworking, with resorting and redistributing of some of these older sediments, by wave action and currents, is believed to have continued to the present time.

All of the samples of bottom sediments are unconsolidated, which is in keeping with a young age, and the clays and silty clays are comparatively soft. Unfortunately, the thicknesses of the various textural classes of sediment on the floor of the Bay are unknown until systematic coring is carried out. It is considered by the writer, however, that the thicknesses of certain bottom sediment types on some parts of the floor are fairly great.

The distribution of the various sediment textural classes generally appears to be related to the submarine topography. The clays and silty clays are found in the deep water, and the texture of the sediments usually becomes coarser as the water shoals. Distance from land and river mouths also appears to influence the sediment distribution. Usually there is a shoreward increase of grain size.

In sheltered parts of the Bay where there is little or no erosion of the coast, such as Swan Bay, Geelong Outer Harbour and Corio Bay, sediments of fine particle-size (clay, silty clay, clayey sand, &c.) occur in comparatively shallow water close to the shore. In these waters where currents are very weak and the power of wave action is usually restricted, fairly rapid sedimentation is apparent at certain places adjacent to the shore, and constant dredging of the shipping channels in Corio Bay and Geelong Outer Harbour is necessary to maintain them at a fixed depth. The clay and silt-size particles, which form such a large part of these bottom sediments, might partly have been (*a*) transported in suspension from other parts of the Bay, (*b*) brought into the areas by small streams nearby, and (*c*) derived from the marine erosion of rocks and unconsolidated detrital materials at certain places along the neighbouring coast. Many of the sand-size particles in the bottom sediments of these sheltered parts of Port Phillip Bay are fragments of marine skeletal material. In fact, shell fragments constitute nearly all the sand-size particles in the clayey sand of Swan Bay and the silty sand off Point Wilson, and they make up much of the sand and clayey sand adjacent to the southern shore of Geelong Outer Harbour. Although Tertiary sediments containing an appreciable content of quartz occur at certain places around the shores of Corio Bay and on the southern shore of Geelong Outer Harbour, many of the grains are of fine particle-size, and those of sand size liberated by marine erosion have generally not been transported far seaward. The fairly large areas of clay in Corio Bay and Geelong Outer Harbour occur in water generally deeper than that in which the silty clays occur, in keeping with the more normal distribution pattern of sediment types. The presence of the long "tongue" of silty sand that extends southward from Point Wilson appears to be related to the shoaling there; and the area of clayey sand that extends from the northern shore of Corio Bay southward for up to 1½ miles appears also to be related to the occurrence of very shallow water.

Adjacent to the north-western shore of Port Phillip and for distances of up to about 5 miles seawards, conditions are usually quieter than in the eastern part of the Bay, since the prevalent winds which produce powerful waves come from the south-west, and the very gradual shoaling in this north-western region causes a dissipation of wave energy. As Jutson (1931) has observed, sedimentation is taking place along the north-western shore of the Bay and has been taking place for several thousand years; the area reclaimed by the mid-Holocene fall in sea-level has been added to by the accumulation of marine deposits at present sea-level. In this north-western region, extending from the shoreline seaward to depths of about 8 fathoms, the main sediment textural classes are sand and silty sand. The large area of sand to the east of the Werribee and Little River mouths has a delta-like form which, at least partly, appears to be due to sediment brought into the Bay by these rivers. Although normally they are relatively unimportant streams with shallow mouths, during periods of flooding their size increases considerably and they discharge appreciable quantities of detrital material into the Bay. At such times, as well as carrying clay and silt-size particles, they may transport some sand-size particles by rolling and saltation. It seems probable, however, that much of the sand to the east of the Werribee and Little River mouths is reworked material that originally came from these rivers in early Holocene and late Pleistocene times. The pebbles of vein quartz, sandstone and some of the other rock pebbles found in the sand as far as 2 miles offshore, most probably came from the ancestral Werribee and Little Rivers; they may have been derived from sub-basaltic gravels or other formations and have been transported and originally deposited during pluvial periods. Likewise, the pebbles of sandstone, quartz and basalt found in the silty sand up to 2 miles offshore from Point Cook and Point Gellibrand have probably come from the old rivers that flowed over the floor of the Bay before it was flooded by the sea about 6,000 or 7,000 years ago.

As Jutson (1931) considered, it is probable that some of the detrital material of fine particle size in the north-western part of Port Phillip Bay has come from the eastern side of the Bay by current and wave-action as well as from the Yarra and Maribyrnong Rivers since mid-Holocene times. The fact that basalt is the most common type of pebble in the sediment samples from this north-western part of the Bay is in keeping with the widespread occurrence of basalt on the adjacent land and its occurrence as submarine rock outcrops in the region. As mentioned above, fragments of basalt are found in the sand as far as 5 miles to the east of the Werribee River mouth. The generally higher content of marine skeletal material in the sands and silty sands off the north-western shore of the Bay compared with that off the eastern shore would seem to be due to the greater molluscan life in the quieter waters of the north-western region; the shell content is also significantly higher as the quartz grains in these sandy sediments are less abundant than in those off the eastern coast. The mineral species present in the small heavy fraction of the bottom sediments from the north-western part of the Bay suggest a mainly basaltic source, and it is probable that they were derived largely from the Newer Volcanic basalt.

The floor of certain parts of Hobson's Bay and of the area immediately to the south have been considerably affected by the dredging of shipping channels and the dumping of dredged materials; the original distribution of bottom sediment types has consequently been changed considerably. The catchment of the Yarra and Maribyrnong Rivers comprises 2,200 square miles, but by the time these rivers reach Melbourne they are normally sluggish streams which have lost their burden of sand but still carry much silt and clay. In the central and western parts of Hobson's Bay, the sandy silt, which is the predominant bottom sediment, appears to represent mainly river-borne detritus. The clay of the dredged shipping channels is considered to have been brought down by the ancestral Yarra in late Pleistocene and early to mid-Holocene times.

The sandy sediments of the eastern part of Hobson's Bay, and those of the continuation of this coastal belt to the south at least as far as Mordialloc, seem to have been derived mainly from the poorly consolidated Tertiary sandstones and Quaternary sands that occur as cliffs along the shore. Erosion is evidenced along this section of the coast by the need for erecting marine retaining walls, &c., at various places; and the common presence of submarine rock outcrops near the shore suggests that marine erosion and recession of the coastline has been taking place for a considerable time. The coastal erosion on this and other sections of the eastern side of the Bay seems to be caused almost entirely by the power of the waves formed by strong southerly and south-westerly winds. Tidal currents are relatively weak in the northern part of Port Phillip; the active currents are mainly longshore ones associated with strong winds. Although these currents are not important as erosive agents, they are of importance in transporting detrital material from place to place. Longshore drift of material near-shore is known to be considerable in this region.

Particularly after heavy rain in the Yarra River watershed, detrital material discharged into the Bay may be transported quite considerable distances southwards, to be added to the material supplied by wave erosion of the coast.

In this north-eastern part of Port Phillip the derivation of the coarser constituents in the sands and gravelly sands from the Tertiary sediments in the shore platforms and cliffs is apparent. Granules and pebbles of ferruginous sandstone, sandstone, ironstone and chert are quite common in the bottom sediments, and were found as far as $1\frac{1}{4}$ miles offshore. The actual presence of this coastal belt of sand composed mainly of ironstained quartz grains also suggests derivation from the adjacent Tertiary sediments, which have a high content of ironstained quartz grains. Carroll (1949, p. 107) found that the Tertiary brown sandstone at Beaumaris contained an average of 81 per cent. sand and 19 per cent. clay, and that the practically unconsolidated white sandstone undergoing rapid erosion in the cliffs at Mentone contained an average of 90 per cent. sand and 10 per cent. clay. The heavy mineral in these Tertiary sediments, described by Carroll (1949), also have a similarity with those observed in the sand samples from the north-eastern part of the Bay. Whincup (1944), in a paper dealing with the sand deposits between Brighton and Frankston, stated that "all the heavy minerals